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ABSTRACT

The instructor's guide presents material for structuring an engineering fundamentals course covering the basic laws of statistics as part of a mechanical technology program. Detailed behavioral objectives are described for the following five areas of course content: principles of mechanics, two-dimensional equilibrium, equilibrium of internal forces, friction, and cross-sectional calculations. The topical outline presents the five areas divided into sub-topics, indicating the number of lecture periods for each topic. The lecture/recitation methodology (including titles of the text and four references) and student activities are briefly described. Evaluation of students according to accomplishment of the behavioral objectives is outlined in detail with numbers indicating the part of the topical outline where the concepts were taught. A sample lesson plan (with a sample problem and a homework problem) and a sample five-problem, three hour final examination are contained in the guide. (MS)

State of New Jersey
Department of Education
Division of Vocational Education

MECHANICS: STATICS

A Syllabus

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INTRODUCTION

Mechanics:Statics, an engineering fundamentals course in the Mechanical Technology Program, covers the basic laws of statics. A working knowledge of algebra, trigonometry, and the slide rule are the only prerequisites. However, there is a math review in the first week to go over the most common equations. Most of the subject material deals with the drawing of free-body diagrams, and the writing and solving of the equations of equilibrium. After these two concepts have been introduced, their principles are used to solve problems involving simple machines, trusses, frames, and friction. The course concludes with cross-sectional calculations covering centroids and moment of inertia. It is a prerequisite course to the study of Strength of Materials and Machine Design.

OBJECTIVES

In completing all the objectives of this syllabus, only the slide rule will be permitted as an aid in calculations or finding trigonometric functions. (No tables or calculators will be allowed.)

1. Principles of Mechanics

   1.1 Identify all terms related to the fundamental principles, when used in problems to be solved. Typical terms are: component, resultant vector, force, and rigid body. (1.1.1-1.1.3)

   Use the following laws of trigonometry when solving problems: Law of Sines, Law of Cosines, and the Pythagoream Theorem. (1.1.4)

   Find the sine, cosine, and tangent trigonometric functions on the slide rule. (1.1.4)

   Solve two simultaneous equations with two unknowns. (1.1.4)

   1.2 Calculate the resultant of three coplaner forces stating the magnitude and direction. (1.2.1)

   Replace a single force with two forces at 90° to each other (1.2.2)

   Determine the resultant of a system of three nonparallel forces in one plane; calculate its magnitude and direction (1.2.3)

   Determine the resultant of a system of four parallel forces in one plane; calculate its magnitude and direction. (1.2.4, 1.2.5)

2. Two-Dimensional Equilibrium

2.1 Place the force vectors on connections and supports, and state an assumed sense. (2.1.1)

Draw free-body diagrams, and using the principles of (1.2) calculate the reactions at the supports for problems involving simple frames and trusses. (2.1.2, 2.1.3)

2.2 Given a load and a machine, calculate the force needed and the mechanical advantage available to move the load. (2.2.1)

State the friction losses that exist in block and tackle and differential pulleys. (2.2.2)

3. Equilibrium of Internal Forces

3.1 Identify a truss by definition and diagram. (3.1.1)

Using the principles of (1.2), calculate the horizontal and vertical reactions on a given truss at the support points, (3.1.2)

Place an imaginary cutting line in order to determine the load in any member. (3.1.3)

Consider the portion of the truss to the right or left of the imaginary cut as a free body by placing force vectors with an assumed sense. (3.1.4)

Using the principles of (1.2), calculate the loads in all the members of a given truss. (3.1.5)

Interpret the positive or negative sign resulting from the solutions of the loads in all members and reactions. (3.1.6)

Using the principles of (1.2), check that all reaction points and connections of a completely solved truss are in a static condition. (3.1.7)

3.2 Identify a frame by definition and diagram (3.2.1)

Calculate the horizontal and vertical reactions on a given frame at the support points. (3.2.2)

Draw the free-body diagrams of all members of the frame (3.2.3)

Assign force vectors with an assumed sense to all connection points. (3.2.4)

Using the principles of (1.2), calculate the magnitude of all force vectors. (3.2.5)

Interpret the positive or negative sign resulting from the solutions for the magnitudes of the force vectors. (3.2.6)

Using the principles of (1.2), check that all the forces in both the separate members and the whole frame are in a static condition. (3.2.7)

4. Friction

4.1 State what friction is, the different types that exist, and write the governing equation. (4.1.1)

Draw a free-body diagram of a rigid body on a friction surface with correctly sensed and identified force vectors. (4.1.2)

Write the required equilibrium equations from the free-body diagram and solve for the unknown. (4.1.3)

4.2 Using the principles of (4.1), solve for a horizontal force required to move a rigid body on a horizontal plane. (4.2.1)

Modify the free-body diagram and equilibrium equations of (4.1) to account for an angled force. (4.2.2)

4.3 Rotate the coordinate axes of the summation of forces equations and modify the free-body diagram of (4.1) to account for a rigid body on an inclined plane with a force parallel to the plane. (4.3.1)

Modify the free-body diagram of a rigid body on an inclined plane and the associated summation of forces equations to account for a force angled to the plane. (4.3.2)

Define and write the equation for the angle of friction (4.3.3)

4.4 Draw free-body diagrams of and write the necessary equilibrium equations for a system containing two coefficients of friction. (4.4.1 - 4.4.2)

5. Cross-Sectional Calculations

5.1 Define a centroid and write the governing equation.(5.1.1)

Recognize and separate combined geometric shapes, and find their individual centroid coordinates in tables. (5.1.3)

Calculate the centroid of a composite area of three different shapes. (5.1.3)

5.2 Identify geometric shapes, find the equations for the rectangular moment of inertia in tables, and calculate the rectangular moment of inertia about an axis passing through the centroid. (5.2.1)

Given tables of structural shape parameters, calculate the moment of inertia of a composite structural shape about an axis passing through the centroid using the parallel-axis theorem. (5.2.2)

Given tables of structural shape parameters, calculate the radius of gyration of a structural shape composite about an axis passing through the centroid. (5.2.3)

Distinguish between area and polar moment of inertia, and calculate the polar moment of inertia. (5.2.4)

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METHODOLOGY

The lecture/recitation periods will be used primarily to present the material in the text and references that pertain to the objectives. Theory will be explained, sample problems will be solved, and questions will be answered. Homework assignments will take the form of text readings and problem solving. Preliminary and final exams will consist entirely of material presented in class and in homework assignments.

Text: *Mechanics*, Breneman, Third Edition, McGraw-Hill Book Co., New York.

References:

Introduction to Mechanics, Levinson, Prentice-Hall, Inc., Englewood Cliffs.

Engineering Drawing and Design, Jensen, McGraw-Hill Book Co., New York.

"Machinery's Handbook", Oberg and Jones, 19th Edition, Industrial Press, Inc., New York.

Vector Mechanics for Engineers, Statics, Beer and Johnston, McGraw-Hill Book Co., New York.

STUDENT ACTIVITIES

Students will be expected to take legible notes during the lecture/recitation periods (4 hours/week). They should be prepared to ask questions in order to clarify specific points. If an in depth discussion is necessary it is the responsibility of the student to make arrangements to meet with the instructor outside of class. The students will be expected to do all homework such as reading assignments and problem solving on time. There will be three full-period exams and a final exam given in order to evaluate the students' ability to complete the objectives.

EVALUATION

Acceptable slide rule calculations will be accurate to three significant figures for the C & D scales and two significant figures for trigonometric angles.

1. Principles of Mechanics

   1.1 Acceptable knowledge of basic terms and definitions will be demonstrated by being able to recognize them in problems and thus determine what is asked. (1.1.1-1.1.3)

   Given a problem with one or more unknowns, acceptable knowledge of basic math is demonstrated by selecting, writing, and solving the correct equation. (1.1.4)

   1.2 Acceptable composition and resolution of forces is demonstrated by correct application of the math review fundamentals. (1.2.1-1.2.2)

   Acceptable summation of coplaner forces is demonstrated by resolving each force into horizontal and vertical components, tabulating and summing the components, and using the two summations of the component forces to determine the direction in degrees. (1.2.3)

   An acceptable solution of parallel forces in one plane has a sum of the forces equation showing the magnitude and a sum of the moments equation showing the location. (1.2.4-1.2.5)

2. Two-Dimensional Equilibrium

   2.1 Acceptable knowledge of free-body diagramming of connections and supports is demonstrated by correctly placing force vectors on connections using rollers, smooth surfaces, pins and cables, and assigning a sense. (2.1.1)

   Acceptable knowledge of simple frames and trusses is demonstrated by drawing a correct free-body diagram, calculating the support reactions with summation of moments equations. (2.1.2-2.1.3)

   2.2 Demonstrate that calculations of simple machine problems contain proper free-body diagrams and demonstrate written and solved summation of moments and summation of forces equations. (2.2.1)

   Demonstrate that correct statements of friction losses include the necessary load percentage increase for block and tackle pulleys and differential pulleys. (2.2.2)

3. Equilibrium of Internal Forces

   3.1 A proper definition of a truss states that the members are straight, not continuous through any connection, and are supported and loaded only at connection points. (3.1.1)

   Correct calculations for reactions contain properly written equations of equilibrium and are checked. (3.1.2)

   A correct imaginary cutting line cuts the member whose load is desired and not more than two other members. (3.1.3)

A correct free-body diagram places force vectors to assume all members in tension by directing the force vectors in the sense of the free end of each member (3.1.4)

Correct calculations for loads in members contain properly written and solved math review laws and equations of equilibrium. (3.1.5)

Correct determination of resulting sign recognizes that a positive sign in the solution confirms the assumption that member is in tension; a negative sign indicates a wrong assumption, and the member is in compression. (3.1.6)

A proper check for static condition takes a connection that has not been used for any solutions and has the summation of forces equations written for it. (3.1.7)

3.2 A proper definition of a frame states that the members can be continuous through any pin connection and that the forces may not be applied at the connections thus causing the member to bend. (3.2.1)

Correct calculations for reactions contain properly written equations of equilibrium and are checked. (3.2.2)

A correct separate member drawing resembles an exploded assembly drawing. (3.2.3)

Correct free body diagrams have all component force vectors at each pin oppose each other on any two connected members. (3.2.4)

Correct calculations for pin loads contain properly written and solved math review laws and equations of equilibrium. (3.2.5)

Correct determination of resulting sign recognizes that a positive sign in the solution confirms the assumption that the force vector sense was correct; a negative sign indicates a wrong assumption. Thus the actual force direction is opposite. (3.2.6)

A proper check for static condition takes a pin connection on each separate member and has a summation of moments equation written for it. (3.2.7)

4. Friction

4.1 Acceptable knowledge of friction definitions include what it does, the difference between static and kinetic, and the correct equation. (4.1.1)

Correct free-body diagrams contain properly sensed force vectors for weight, normal reaction, force, and the friction force. (4.1.2)

Correct summation of forces equations contain all variables from free-body diagrams and equal zero. (4.1.3)

4.2 Correct horizontal plane friction solutions contain a free-body diagram, and properly written and solved equilibrium equations. (4.2.1-4.2.2)

4.3 Correct inclined plane friction solutions contain a free-body diagram and properly written and solved rotated axis equilibrium equations. (4.3.1 - 4.3.2) Acceptable angle of friction definition states that the tangent of the angle of inclination is equal to the coefficient of friction and, at this condition, the body is on the point of starting to slide. (4.3.3)

4.4 Correct biaxial force system solutions contain a free-body diagram and a properly written and solved equilibrium equation. (4.4.1-4.4.2)

5. Cross-Sectional Calculations

5.1 Acceptable definition of a centroid states that it is the point through which the resultant area passes. Write the equation for X. (5.1.1)

Acceptable dexterity in recognizing shapes and finding them in tables results in correct equations for calculating the centroids. (5.1.2)

Acceptable centroid calculations for a composite area contain tabulated values for areas, corresponding centroidal distances, area moments, and summations. (5.1.3)

5.2 Acceptable familiarity with moment of inertia calculations for geometric shapes results in correct equations and solutions (5.2.1)

Acceptable knowledge of the parallel-axis theorem is demonstrated by correctly calculating it for a composite of three structural shapes. (5.2.2)

Acceptable knowledge of radius of gyration is demonstrated by writing and solving the correct equation for a composite of three structural shapes. (5.2.3)

Acceptable knowledge of polar moment of inertia is demonstrated by stating that it is used for rotating shafts, that the calculation is about an axis perpendicular to the cross-sectional area, and writing and solving the equation for a tube. (5.2.4)

GRADING

All work and examinations will be marked with the standard letter grade system (A, B, C, D, and F). The main categories for evaluation will be accuracy, clarity, and neatness. Accuracy in drawing free-body diagrams and in writing and solving equations will demonstrate knowledge. The clarity and neatness of this work will demonstrate quality.

Category	Point Value
Accuracy	90%
Clarity	5%
Neatness	5%

All work will be graded as shown in the sample below.

A - 68

C - 3

N - 4

75 - C

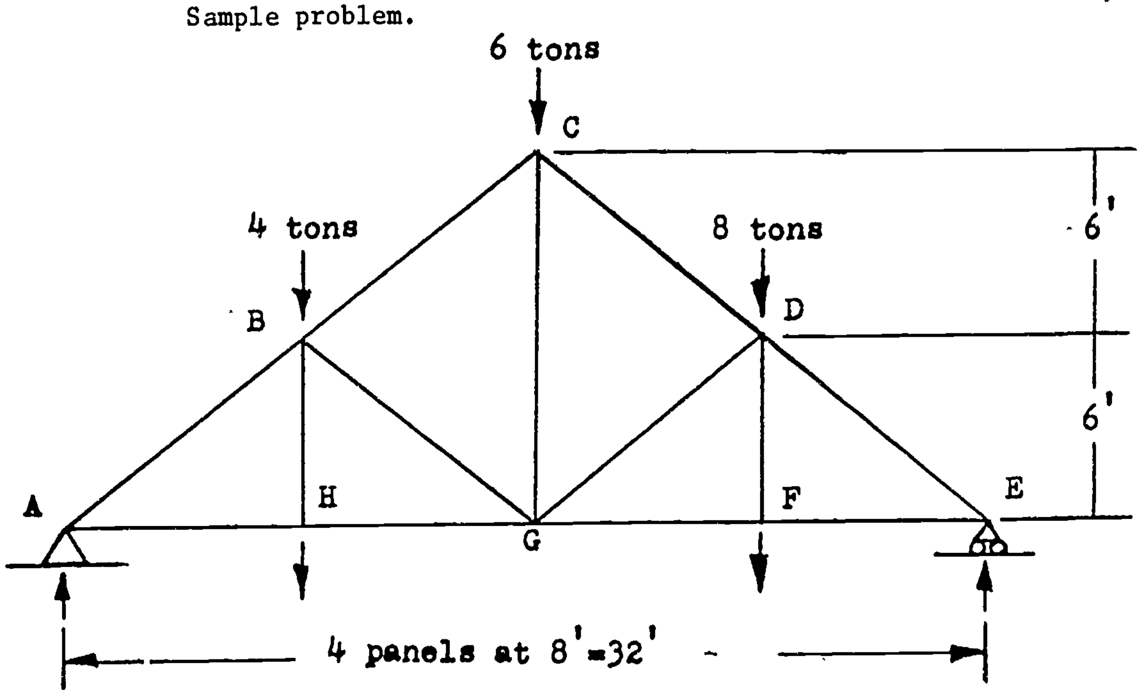
SAMPLE LESSON PLAN

Lesson No. ____ Trusses

Definition: Trusses are structures which are composed of members in a single plane. The members are straight, connected at their ends by pins which are assumed to provide no resistance to turning, and not continuous through any connection. Such structures are supported at two points and are loaded so that the loads are applied only to the joints or intersections of the members of the truss.

A truss is an example of an equilibrium force system which can be solved by making use of free-body diagrams and applying the equations of equilibrium. Solutions in this course will assume that the weight of the truss and the weight of the flooring or roofing material is negligible. Only the external loads applied to the truss at the pin connections and supports will be considered.

Sample problem.



1. CALCULATE REACTIONS AT "A" AND "E".

$$\circlearrowright^{+} \Sigma M_A = (1 \times 8) + (4 \times 8) + (6 \times 16) + (1 \times 24) + (8 \times 24) - (E_y \times 32) = 0$$

$$E_y = \frac{8+32+96+24+192}{32} = 11 \text{ TON}$$

$$\circlearrowleft^{+} \Sigma M_E = (-1 \times 8) + (-8 \times 8) + (-6 \times 16) + (-1 \times 24) + (-4 \times 24) + (A_y \times 32) = 0$$

$$A_y = \frac{8+64+96+24+96}{32} = 9 \text{ TON}$$

CHECK:

$$+\uparrow \Sigma F_y = -4 - 6 - 8 - 1 - 1 + 11 + 9 = 0$$

$$20 - 20 = 0$$

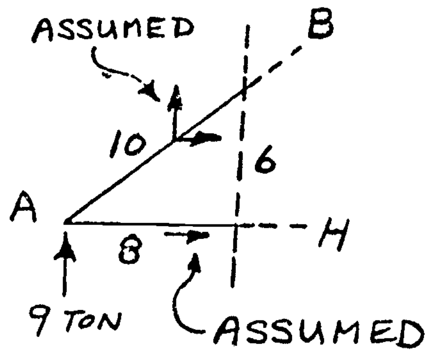
NO HORIZONTAL LOADS: $A_x = 0$

In order to determine the load in any member, form free-body diagrams by cutting that member and not more than two other unknown members with an imaginary line. Both straight cuts and circular cuts around connections will be necessary. On the resulting free body, assume a tensil sense for the force vector that is placed on each unknown member that is cut. If the resulting solution is positive, the member is in tension. A negative answer indicates that the member is in compression.

When solving for unknown members in the free-body diagrams, calculations will be simplified if members can be selected that carry the only unknown horizontal or vertical load for that joint. In this manner, less involved summation of forces equations may be written instead of the more tedious summation of moments equations. Note that the forces in all angled members in the free body diagrams have been resolved into their vertical and horizontal components.

Start at left support A, with a cutting line through members AB and AH. Then, move deeper into the truss with successive cutting lines. Since this truss is symmetrical, we will stop at the middle, and you students will repeat the same operations starting at the right support E for homework.

$$+\uparrow \Sigma F_y = A_y + AB_y = 0$$
$$9 + AB_y = 0$$
$$AB_y = -9 \text{ TON}$$



$$\frac{AB_x}{4} = \frac{AB_y}{3} = \frac{-9}{3}$$

$$AB_x = -12 \text{ TON}$$

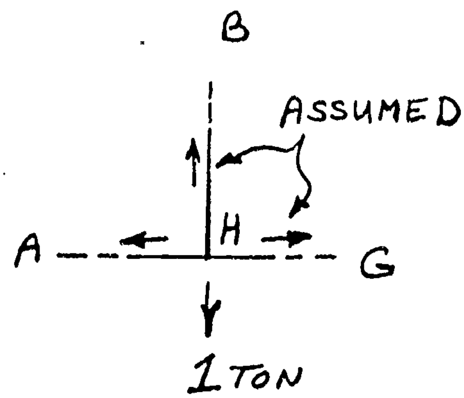
$$\frac{AB}{5} = \frac{AB_x}{4} = \frac{AB_y}{3}$$

$$AB = -15 \text{ TON (COMP.)}$$

$$\overset{+}{\rightarrow} \Sigma F_x = AH + AB_x = 0$$
$$AH - 12 = 0$$
$$AH = 12 \text{ TON (TEN.)}$$

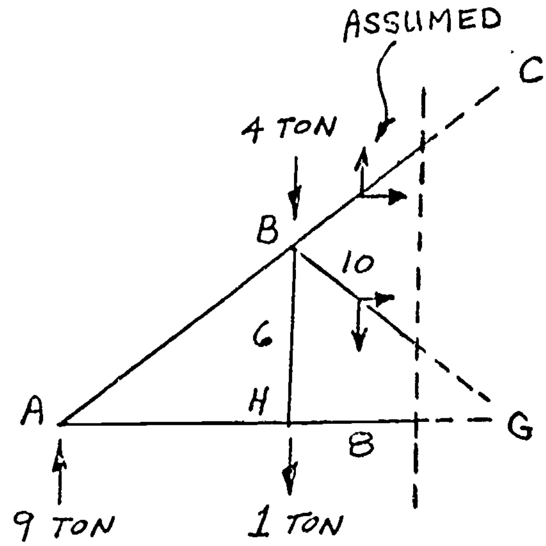
$$\overset{+}{\rightarrow} \Sigma F_x = AH + HG = 0$$
$$-12 + HG = 0$$
$$HG = 12 \text{ TON (TEN.)}$$

$$+\uparrow \Sigma F_y = HB - 1 = 0$$
$$HB = 1 \text{ TON (TEN.)}$$



The components of a force can be placed anywhere on the line of action of the force as long as the components intersect the line of action at the same point.

Visualizing that BC_y and BC_x are placed very close to point A so that the moment of BC_x about point G closely approximates



$$\circlearrowleft + \Sigma M_G = (9 \times 16) + (-1 \times 8) + (-4 \times 8) + (BC_y \times 16) = 0$$

$$BC_y = \frac{-144 + 8 + 32}{16}$$

$$BC_y = -6.5 \text{ TON}$$

$$\frac{BC_x}{4} = \frac{BC_y}{3} = \frac{-6.5}{3}$$

$$BC_x = -8.67 \text{ TON}$$

$$\frac{BC}{5} = \frac{BC_x}{4} = \frac{BC_y}{3}$$

$$BC = -1.08 \text{ TON (COMP.)}$$

$$+\uparrow \Sigma F_y = 9 - 6.5 - 1 - 4 - BG_y = 0$$

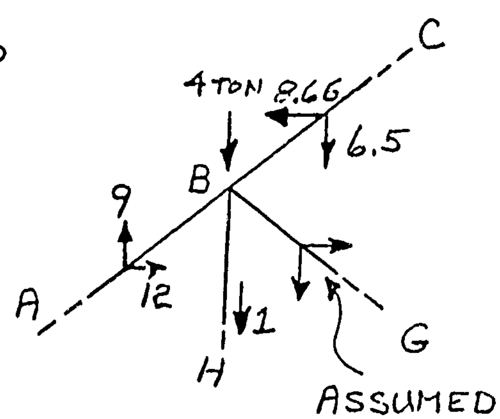
$$BG_y = 2.5 \text{ TON (TEN.)}$$

$$\frac{BG_x}{4} = \frac{BG_y}{3} = \frac{-2.5}{3}$$

$$BG_x = -3.33 \text{ TON}$$

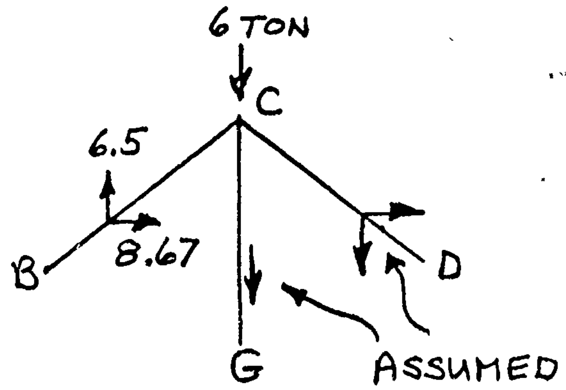
$$\frac{BG}{5} = \frac{BG_x}{4} = \frac{BG_y}{3};$$

$$BG = -4.16 \text{ TON (COMP.)}$$



Check:

$$\overset{+}{\rightarrow} \Sigma F_x = -8.67 + 12 - 3.33 = 0$$
$$12 - 12 = 0$$



$$\overset{+}{\rightarrow} \Sigma F_x = 8.67 + CD_x = 0$$
$$CD_x = -8.67 \text{ TON}$$

$$\frac{CD_y}{3} = \frac{CD_x}{4} = \frac{-8.67}{4}$$
$$CD_y = -4.6 \text{ TON}$$

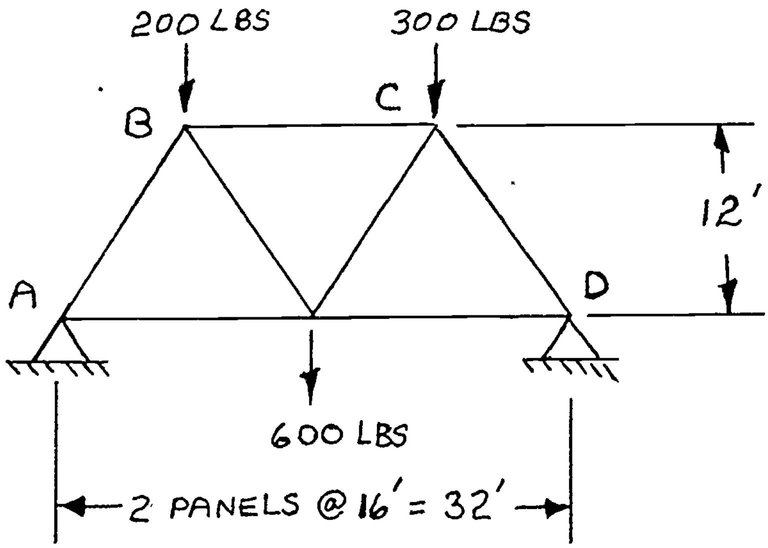
$$\frac{CD}{5} = \frac{CD_y}{3} = \frac{CD_x}{4}$$
$$CD = -10.85 \text{ TON (COMP.)}$$

$$+\uparrow \Sigma F_y = 6.5 + 4.6 - 6 - CG = 0$$
$$CG = 5.1 \text{ TON (TEN.)}$$

SAMPLE FINAL EXAMINATION

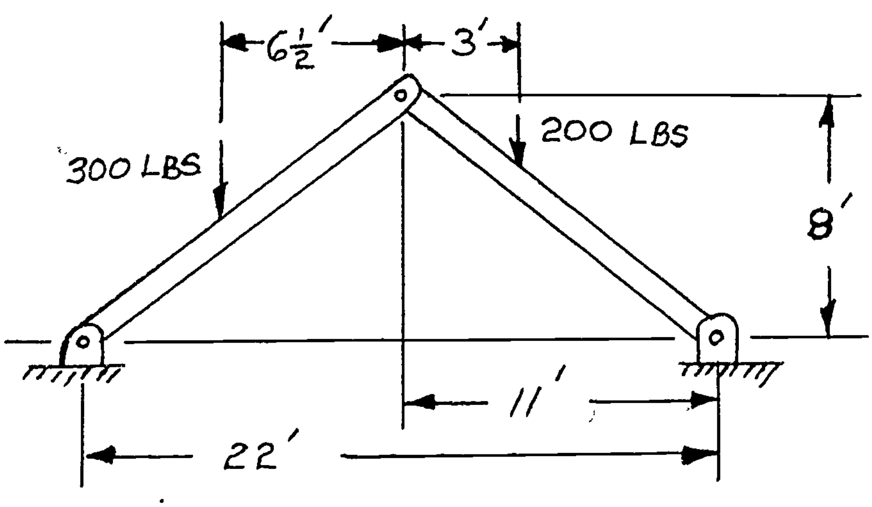
Time: 3 hours
Do all problems. Show all work.
Each problem is worth 20 points.

NO. 1



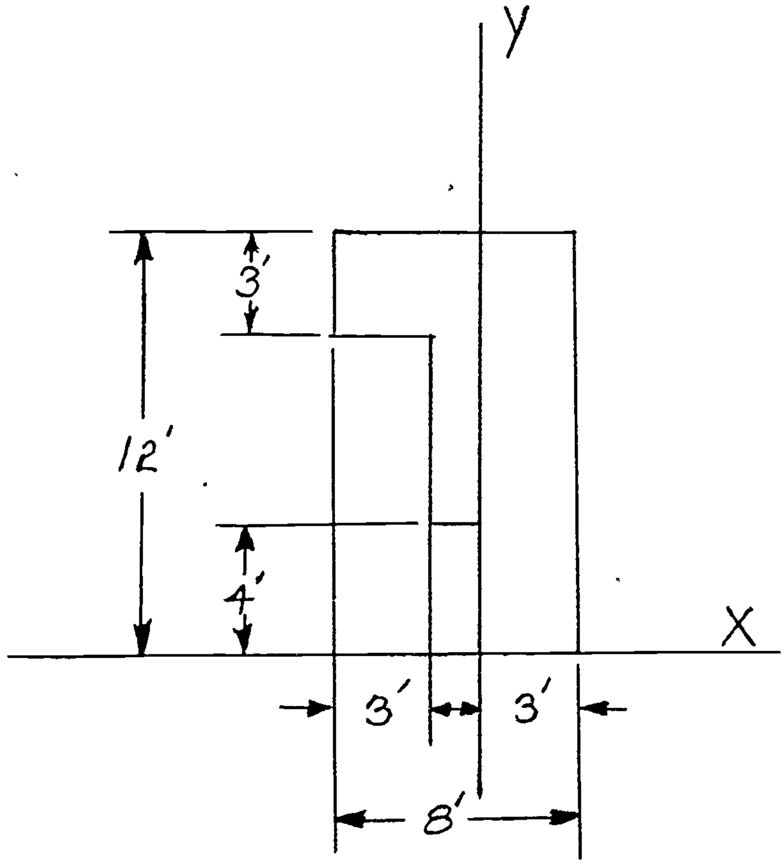
1. Find the reactions at supports A and D.
2. Draw free-body diagrams.
3. Find the vertical and horizontal components of the loads in all members.
4. Check solutions.

NO. 2



1. Draw a free-body diagram.
2. Calculate the reactions at the support A and C.

NO. 3



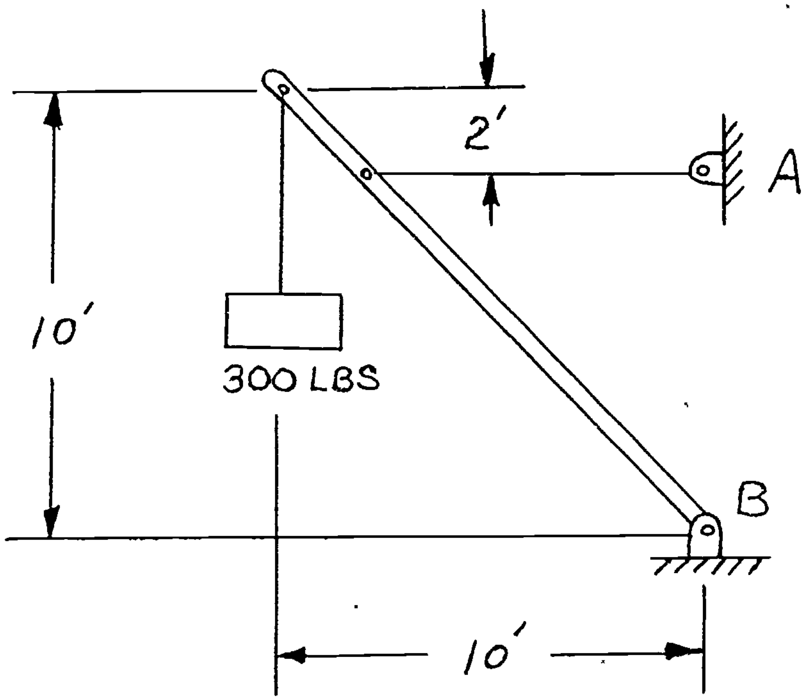
Locate the centroid of the section shown with reference to the X-Y axes.

NO. 4

A 250 pound weight is resting on a 25-degree inclined plane. Draw a free-body diagram and calculate the force, parallel to the plane, necessary to move the weight up the plane.

$\mu = .25$

NO. 5



1. Draw a free-body diagram.

2. Calculate the reactions at the supports A and B.